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Temperature Controlled CO_2 Laser Welding of Soft Tissues: Urinary Bladder Welding in Different Animal Models (Rats, Rabbits, and Cats)

Bernard Lobel, MD,[1] Ophir Eyal, PhD,[2] Noam Kariv, DVM,[3] and Abraham Katzir, PhD[2]*

[1]*Department of Urology, Centre Hospitalier Pontchaillou, Rennes, France*
[2]*School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel*
[3]*Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel*

Background and Objective: **Laser welding of tissues is a method of closure of surgical incisions that, in principle, may have advantages over conventional closure methods. It is a noncontact technique that introduces no foreign body, the closure is continuous and watertight, and the procedure is faster and requires less skill to master. However, in practice, there have been difficulties in obtaining strong and reliable welding. We assumed that the quality of the weld depends on the ability to monitor and control the surface temperature of the welded zone during the procedure. Our objective was to develop a "smart" fiberoptic laser system for controlled temperature welding.**
Study Design/Materials and Methods: **We have developed a welding system based on a CO_2 laser and on infrared transmitting AgClBr fibers. This fiberoptic system plays a double role: transmitting laser power for tissue heating and noncontact (radiometric) temperature monitoring and control. The "true" temperature of the heated tissue was determined by using an improved calibration method. We carried out long-studies of CO_2 laser welding of urinary bladders in various animal models. Cystotomies were performed on the animals, and complete closure of the bladder was obtained with a surface temperature of 55 ± 5°C at the welding site.**
Results: **In early experiments on 31 rats, the success rate was 73%. In later experiments with 10 rabbits and 3 cats, there was an 80% and a 100% success rate, respectively.**
Conclusion: **The success rate in these preliminary experiments and the quality of the weld, as determined histologically, demonstrate that temperature controlled CO_2 laser welding can produce effective welding of tissues. The fiberoptic system can be adapted for endoscopic laser welding. Lasers Surg. Med. 26:4–12, 2000.** **© 1999 Wiley-Liss, Inc.**

Key words: infrared thermometry; infrared fibers; laser–tissue interaction; tissue welding; urinary bladder

INTRODUCTION

Laser welding of tissues is an experimental surgical technique for the bonding of tissues by using a laser beam. This method is potentially more advantageous than the conventional suturing technique because it is a noncontact method, which does not introduce foreign materials, and it is capable of forming an immediate watertight seal. There have been two fundamental approaches to laser bonding of tissues: (1) Laser welding: heating of the approximated edges of tissues by a laser beam. (2) Laser soldering: applying a biological solder to the approximated edges

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*Correspondence to: Abraham Katzir, PhD, Tel Aviv University, Tel Aviv 69978, Israel. E-mail: katzir@ccsg.tau.ac.il

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and heating the solder. In the case of laser welding, some researchers have used lasers (e.g., GaAs or Nd:YAG), whose radiation penetrated deeply into tissue, whereas others have used lasers (e.g., CO_2) whose radiation is highly absorbed in the top surface layer. The "end point" was obtained by visual signs, such as changes in the color of the welded tissue. In the case of laser soldering, the researchers used various biological "solders," such as albumin or fibrin that were heated by the lasers. These served as "biological scaffolding" that strengthened the welded zone. Laser welding and laser soldering have been discussed in several review articles [1,2]. Yet, these procedures have not yet been widely used clinically, because reliable results have been difficult to obtain.

In urology, for example, several types of tissues have been successfully bonded by researchers who used various laser systems [3,4] for laser welding or laser soldering. Recent publications have focused on extraperitoneal reimplantation of ureters in dogs [5], laser-assisted enterocystoplasty in rats [6], laser welding of canine ureters in vitro [7], and laparoscopy [8,9]. It has been difficult to obtain reproducible results in these experiments.

Others and we have argued that sensing and continuously controlling the surface temperature of the welded tissue during the procedure is an essential issue. Many biological phenomena depend exponentially on the temperature T and only linearly on the welding time t. For example, let us assume that optimal welding conditions are obtained for surface temperature T = 60°C = 333°K and welding duration of t = 12 seconds. Previous (unpublished) theoretical work done by us indicates that if the welding duration t is decreased by 25% to 9 seconds or increased by 25% to 15 seconds, good welding will still be observed. On the other hand, if the temperature T is decreased by 15°C to 45°C = 318°K, no welding will be observed. If the temperature is increased by 15°C to 75°C = 348°K, there will be an excessive thermal damage that may lead to weak welding. The welding strength is much more sensitive to small changes in the welding temperature than to small changes in the welding duration! By careful monitoring and control of the welding temperature, one may thus standardize the parameters and eliminate the subjective interpretation of the results. It is hoped that this control may lead to a reliable and repeatable laser welding of tissues.

Several earlier works already used temperature-controlled tissue bonding. Some of the works discuss laser welding [10–13] and others discuss laser soldering, by using biological glues [14,15]. In most of these works, a laser beam was focused by a lens onto a small area to be heated. A remote infrared thermometer was used to measure the surface temperature of the same area of irradiated tissue. A feedback loop was used to control this temperature during the laser heating procedure. The focusing lens and the detector can be mounted in a single hand-piece. The accurate calibration of the true temperature of the heated area is still needed. Such a system cannot be used endoscopically.

We developed a *fiberoptic* laser welding system that has some advantages. The distal tips of the two fibers were mounted in a slim hand-piece, making it easy to carry out the welding procedure. The radiometer was calibrated, by using an improved calibration procedure, which yielded the "true" surface temperature of the welded area. The system can be used for endoscopic laser welding and soldering applications.

This system has been previously used by us [16] to weld 18-gauge needle puncture wounds in rat urinary bladders, and to weld incisions in the urinary bladders of rats [17] and in the corneas of rabbits [18]. The *acute* sealing strength was determined by burst pressure measurements. Maximal strength was recorded when the temperature of the welded spot was 55°C and the exposure time was 12 seconds. In the present work, we used the same system to weld large urinary bladder openings (cystotomies) in animal models. Early experiments were carried out on rats and rabbits, whose bladders are thin. Later experiments were carried out on cats, whose bladders are much thicker and more similar to that of a child. The goal was to demonstrate the feasibility of complete bladder closure and to determine the long-term survival rate after welding. It is hoped that these experiments will lead to clinical applications of laser welding in urology and in other medical disciplines.

MATERIAL AND METHODS

CO_2 Laser Heating of Tissues

Laser welding is based on the heating (e.g., controlled heating) of tissues. Some researchers have used for this application lasers emitting visible or near infrared radiation (e.g., Nd:YAG or GaAs lasers), whose radiation penetrated deeply into the tissue and heated a layer of thickness of

few mm. It is very difficult to determine accurately in this case the temperature distribution inside the heated layer. Other researchers used the CO_2 laser, emitting radiation at 10.6 μm. This radiation is highly absorbed by soft tissues; therefore, it heats only the topmost layer of the tissues. In such a case, the infrared equipment discussed below is capable of accurately measuring the temperature of the heated topmost layer. In this work we used a CO_2 laser (Synrad, Model D48-1) for the welding experiments. This was an RF excited laser, which was modulated to operate ON and OFF at 10Hz, so that the tissue was irradiated by a train of pulses at a duty cycle of 0.5. We did not use any biological solder or glue.

Noncontact Temperature Measurements by Infrared Radiometry

The surface temperature T of tissues can be determined by measuring the infrared (IR) radiation emitted by the surface. For any warm body, the intensity of the radiation emitted from a surface area A is given by the expression $I = A\varepsilon\sigma T^4$, where σ is a constant. The emissivity ε is determined by the surface properties of the body. For tissues, ε is determined mostly by the water content: if the water content is very high (such as in soft tissues), ε is almost 1, but if the tissue is dry, the emissivity decreases significantly. It turns out that for animals and for the human body, most of the emitted infrared radiation is in the *middle* infrared (MIR) spectral range between 3 and 30 μm. The peak of this emission is near 10 μm. An infrared radiometer is an instrument containing an infrared detector, which is used to measure the radiation emitted from an area on a surface. If the area A and the emissivity ε of the surface are known, these radiometers can be used to determine the surface temperature with accuracy better than 0.1°C. The accuracy of a radiometer depends on the calibration, and an inaccurate determination of A or ε may lead to erroneous results. The response time of the radiometer depends on the infrared detector used and the electronics. Radiometers based on pyroelectric detectors, such as the one we used, have response times of a fraction of a second. The radiometer used in this work had a temperature accuracy of 0.1°C and a response time of 0.1–0.2 seconds.

Infrared-Transmitting Optical Fibers

Standard optical fibers are made of silica glasses, and they are highly transparent in the visible and near infrared. They are useful for the transmission of Nd:YAG or GaAs radiation but are totally opaque in the middle infrared and cannot transmit CO_2 laser radiation. We have developed novel fibers for this spectral range. These unique fibers are made of polycrystalline silver halides ($AgCl_xBr_{1-x}$) and are highly transparent in the middle infrared (3–30 μm.). The fibers are flexible, nontoxic, nonsoluble in water, and biocompatible [19–20]. Fibers of diameter 0.5–1.0 mm and lengths up to 10 meters have been made. These fibers can be used for two important applications: (1) A silver halide fiber can be used to deliver CO_2 laser power up to several watts, for heating of tissues in a remote location. The CO_2 laser radiation is focused on the proximal tip of the fiber. The distal tip of the fiber is placed near a sample, and the radiation emitted from the tip diverges and heats an area A on the sample surface. (2) A similar fiber can be used to transmit the infrared radiation emitted from the heated area to an infrared detector. This infrared transmitting fiber, therefore, could be used for fiberoptic radiometry, i.e., for noncontact measurement of the temperature of the heated surface area [20–22].

Fiberoptic System for Temperature-Controlled Heating of Tissues

We have developed a fiberoptic system for monitoring and controlling of the temperature of an area on a tissue surface, in situ and in real time [23]. The system used for laser welding is illustrated in Figure 1. Two silver halide fibers, each of length 1 meter and diameter 0.9 mm, were used. One fiber, termed the "delivery fiber," delivered the CO_2 laser radiation to an area A on the tissue surface. The heated area emitted IR radiation whose intensity was determined by the surface temperature. A second fiber, termed "sensing fiber," delivered the IR radiation emitted from the irradiated area A, to a radiometer, which can be calibrated to yield the surface temperature. A full description of the system, of the calibration procedures, and of the application of the system for laser welding were given in previous publications [23,24]. The CO_2 laser radiation at 10.6 μm, reflected from the tissue, can "blind" the infrared detector that measures the temperature of the heated tissue. One method of overcoming this problem is to use a narrow bandpass rejection filter that blocks the reflected radiation from reaching the infrared detector [23]. Another method [25] makes use of the fact that the welded region is heated by a laser beam that is modulated ON–

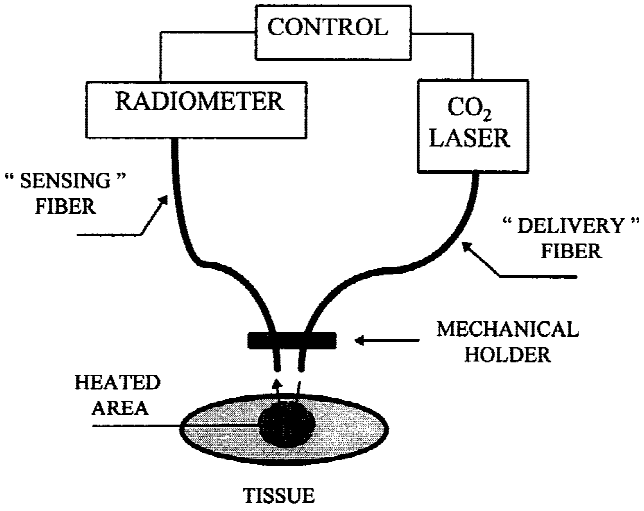

Fig. 1. Schematic drawing of the fiberoptic laser welding system. A mechanical holder grasped the distal tips of two silver halide fibers. The first fiber, termed the "delivery fiber" was used for transmitting the laser beam that heated a spot on the bladder. The second fiber, termed the "sensing fiber," was connected to a radiometer and was used for measuring the surface temperature. The radiometer was connected to a personal computer, and its signal was used to control the laser power, thus controlling the temperature of the heated spot.

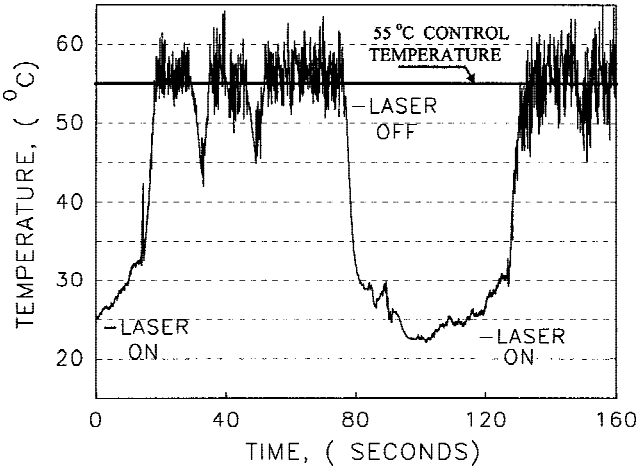

Fig. 2. Temperature measurement during a CO_2 laser welding procedure on the urinary bladder of a rat. The figure shows the degree of control achieved when the laser is operated (ON).

OFF at 10Hz. The radiometer is synchronized, so that the temperature measurement carried on only during the time intervals when the laser beam is OFF.

The radiometer used in this work for the welding experiments was sensitive to the 7–14 μm spectral range, and it generated a voltage signal V that was proportional to the temperature T. This signal was measured by a personal computer (PC) system, which also controlled the laser power, thus controlling the tissue surface temperature. Typically, the CO_2 laser power output at the fiber tip was 300–900 mW. Figure 2 illustrates the real time temperature control achieved during a laser welding experiment on a urinary bladder of a rat.

Improved Calibration Procedures for the Laser Welding System

Immediately before the animal experiments, the radiometer was calibrated by using a sample of tissue. The two fibers tips were held approximately 1 mm above the tissue sample surface by using a holder that allowed the tips to face the same spot. The laser spot on the irradiated surface of the tissue was approximately 2 mm in diameter. The sensing fiber sampled an area of the tissue surface of approximately 2 mm in diameter. The two tips were aligned to achieve the maximal radiometric signal, thus confirming that the radiometer measured the tissue temperature in the area heated by the laser radiation. A thin thermocouple was inserted roughly 0.5 mm beneath the upper surface of the sample. The tissue sample was very slowly heated by the CO_2 laser beam delivered through the "delivery fiber." The 10.6 μm wavelength of the CO_2 laser was strongly absorbed by the tissue; therefore, the thermocouple was not heated directly by the laser energy. The calibration curve was obtained by simultaneously recording the signals from the radiometer and the thermocouple.

The following experiment was carried out to make sure that the calibration procedure is accurate: A spot on the surface of tissue was slowly heated by the laser welding system, and its temperature was kept at some desirable value, which was recorded by the fiberoptic radiometer. Then the laser irradiation was stopped, and a thin thermocouple was immediately brought in contact with the heated spot. The temperature reading obtained by this (second) thermocouple was found to be almost identical to the one obtained by the (first) thermocouple that was buried under the tissue surface. This simple measurement verified the calibration procedure of the radiometer.

Animals

Rats. Thirty-one Sprague-Dawley rats (27 females and four males), weighing 190–300 g each, were included in the experiment. They were anesthetized intraperitoneally with a mixture of

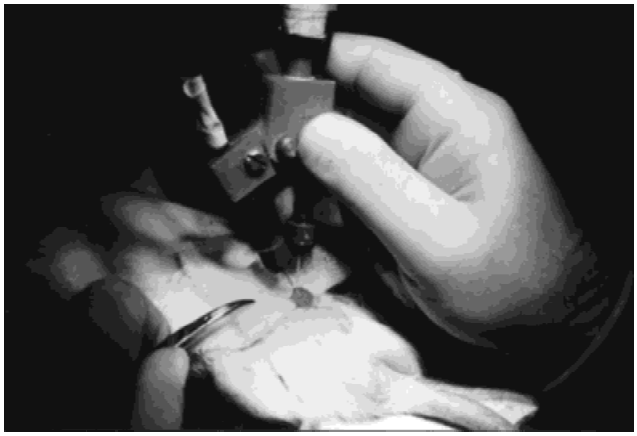

Fig. 3. Photograph of the mechanical holder, schematically shown in Figure 1, during a welding procedure on the urinary bladder of a rat.

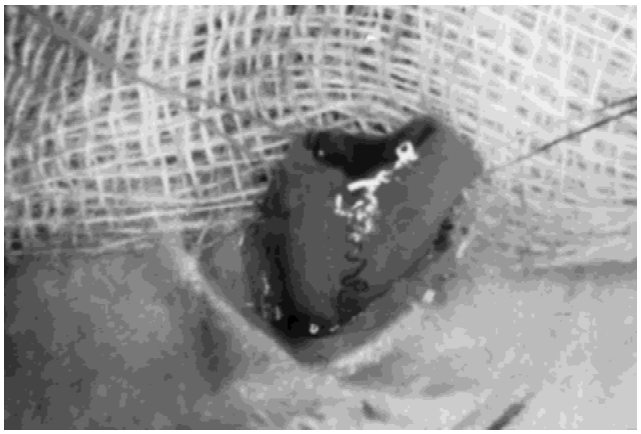

Fig. 4. Large cystotomy in a rat urinary bladder. The temporary sutures shown are needed for better approximation of the edges during the welding procedure.

ketamine (90 mg/kg) and xylazine (10 mg/kg). The bladder opening (cystotomy) varied from 8 to 12 mm.

Rabbits. Ten New-Zealand rabbits (nine females, one male), weighing 1,900–2,700 g each, were anesthetized intravenously by Pentobarbitone (45 mg/Kg). Cystotomies varying from 12 to 19 mm were performed. During the welding procedure, a few temporary sutures were used to approximate the edges of the bladder.

Cats. Three cats (two females and one male), weighing 3,000–4,000 g each, were anesthetized intravenously by pentobarbitone (25 mg/Kg), with cystotomies varying from 10 to 12 mm.

Laser Welding of Urinary Bladders

The experiment began with rats and proceeded with rabbits and cats. The experimental design was identical: animals were placed on a clear diet for 24 hours before surgery. The rats were anesthetized intraperitoneally, whereas the rabbits and cats were anesthetized intravenously. The animals were placed in a supine position, and the abdomens were shaved and subsequently cleaned with polydine. Surgical operations were performed with the aid of 4.5× Zeiss binoculars. Through low midline incisions, the urinary bladders were exposed and widely opened at the dome with scissors while avoiding the main vessels. During the welding, the field was kept dry of blood and urine by using sponges. The distal tips of the two fibers were held together by the handpiece and kept roughly 1 mm above the wound, while the laser heated the tissue (see Fig. 3). The surface temperature of the bladder wall was maintained close to 55°C.

Rats. Two temporary sutures were used for better approximation of the edges (see Fig. 4). Welding was carried out with a power level of 300 mW. The fusion of the tissue edges began with a spot weld lasting approximately 12 seconds at one extremity of the bladder opening. The surgeon completed the weld by moving the fiber tips slowly across the weld line, while the system was controlling the temperature (Fig. 5). The movement of the fiber tip was controlled by the surgeon's hand, and he tried to keep heating each spot of 1 mm for a duration of roughly 10 seconds. The sutures were removed at the end of the welding procedure. In addition to the 31 rats, we used a group of 3 rats as a control group. In these cases, we did not use welding, and the cystotomies were closed with regular Dexon sutures.

Rabbits. For rabbits, that have a thicker bladder wall, the laser power level was again kept at 300 mW and the surface temperature was maintained at 55°C. The welding procedures were carried out at lower speeds, to allow heating of deeper layers. Temporary sutures were again used to assist in approximating the edges of the cut.

Cats. The power output at the fiber tip was increased to 600 mW, and the time to obtain a successful weld was increased, because of the greater thickness of the bladder wall. Bleeding and urinary flow through the cystotomy were a problem, necessitating suction. As in the previous cases, a few temporary sutures were used to approximate the edges of the cut.

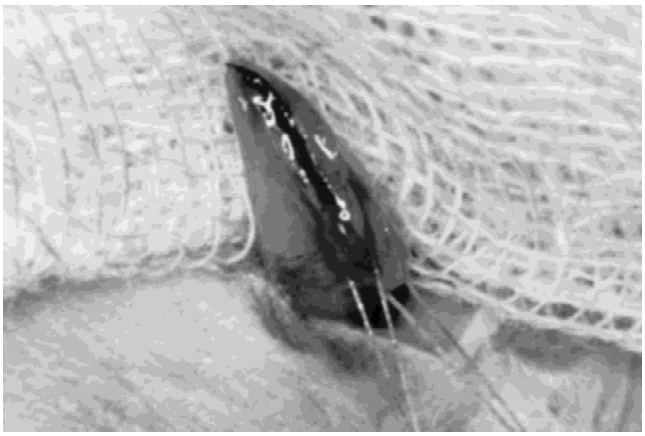

Fig. 5. Rat urinary bladder during the CO_2 laser welding procedure. The edges are approximated by stay sutures.

Postoperative Procedures.

After welding, the bladder was observed for filling. The abdominal wall was then closed by using one layer of continuous Vicryl suture. Some of the animals were killed, to carry out histologic studies. During the postoperative period, all animals were advanced to regular chow and given free access to water. No antibiotics were given. Killing of the rats was performed after days 0, 1, 6, 9, 14, 31. The rabbits were killed after 6, 11, 12, 16, and 35 days. Histologic specimens were stained with hematoxylin and eosin to examine the tissues with light microscopy after the laser procedure. Few rats and rabbits died, and autopsies were carried out on them as well.

RESULTS

Our main objective of the study was to record the animal survival, after urinary bladder welding, with an absence of leaking, to ensure that bladder closure was sufficient and of lasting quality. It should be mentioned that no adhesions were observed in this study. The results are presented in Table 1 and explained below.

Rats

Twenty-seven of the 31 rats survived the CO_2 laser welding for minimum of 48 hours. Of these 27, seven rats (26%) died, six between days 2 and 3, and one died on day 9. Autopsies on those that died revealed urinary leakage with a total breakdown of the weld in four cases. It should be mentioned that during the very first experiments, we had technical difficulties that led to poor temperature control and poor welding. These difficulties led to the early death of some of the rats.

Rabbits

Most of the technical difficulties have been solved by the time we carried out welding experiments on rabbits. All the rabbits remained alive in the same cage apart from two (20%) who died on day 9 and were thereafter autopsied. One rabbit's bladder completely failed to seal. Of the eight animals that survived, six were killed on days 6, 11, 12, 16, 35, and pathologic studies were performed on each to determine the late response to the welding. Scarring was complete after 1 week, and the bladder returned to normal after 6 weeks.

Cats

All cats remained alive and none were killed.

Histology.

In this work, careful histologic observations were carried out only on the rats. One section was taken of each wound. Four of the 31 rats were killed on days 0, 1, and 6 for histologic studies. Macroscopic and microscopic pathologic studies were conducted after the animals were killed. In the week after the operation, the site of the laser-induced lesion was easily located. After 10 days, the scar disappeared and was hard to discern. In these rats, we left stitches at the two extremities of the opening, to mark the limits of the welding for pathology. Typical examples of the cross-section of the bladder wall in the welded regions 10 minutes and 10 days after the procedure are shown in Figure 6. The welded regions is clearly seen at the center of Figure 6A but cannot be observed in Figure 6B.

It was found that 24 hours after welding, there was a continuos muscular layer with small amount of fibrin and hemorrhage and interruption of this layer only at the site of incision. Ten days and 30 days after welding, the bladder wall looked normal with no sign of interruption, inflammation, or scar. Studies of the control group (closure with standard suture) showed that after 24 hours there was interruption of the entire bladder wall, with an acute inflammatory reaction. Ten days after closure, normal epithelial layer appeared but with interruption of the muscular layer with acute inflammation and foreign body reaction near the sutures.

DISCUSSION

The basis of this work is a unique fiberoptic system that is based on a CO_2 laser and a fiber-

TABLE 1. Summary of the Experiments of Laser Welding of the Urinary Bladders of Rats, Rabbits, and Cats

Animal type	No. of animals	Length of the cystotomy (mm)	No. of follow-ups	No. of deaths (among follow-ups)
Rats 190–300 g	31	8–12	27	7 (26%)
Rabbits 1,900–3,000 g	10	12–19	10	2 (20%)
Cats 3,000–4,000 g	3	10–12	3	0

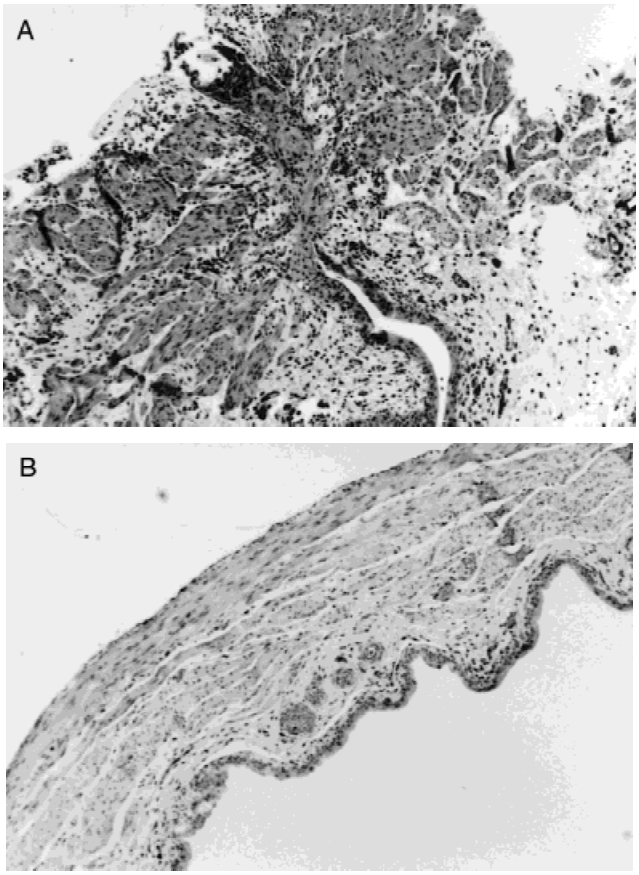

Fig. 6. Photomicrographs of the histologic specimens obtained from the laser welded areas in the urinary bladders of rats. Hematoxylin and eosin stain was used. **A:** The welded zone, 10 minutes after laser welding. Original magnification, 140×. **B:** The welded zone, 10 days after welding. The weld cannot be discerned. Original magnification, 70×.

optic radiometer. One of the major problems in operating such a system is the accurate temperature calibration, mentioned above. In this work, we used an improved calibration method. The calibration was carried out with the help of a thermocouple that was inserted 0.5 mm below the tissue surface. The tissue was heated very slowly during the calibration procedure, and this method ensured that the surface temperature (measured by the radiometer) was equal to the temperature inside the tissue (measured by the thermocouple). That the calibrations and the actual measurements were made in the same configuration ensured that a change of the tissue emissivity ε, which may have occurred during the irradiation, due to water evaporation, was taken into account. The calibration procedure also took into account geometrical factors and nonuniform heating of the small spot on the surface of the tissue caused by the Gaussian profile of the laser beam.

Laser welding of the urinary bladder in different animals is an important step in the in vivo soft-tissue welding model. Shenfeld et al. [24], while using a similar system, characterized the acute phase immediately after welding of an 18-gauge needle puncture in the anterior bladder wall. These researchers found the optimal temperature in the rat bladder model for CO_2 laser-assisted welding to be 55 ± 2.5°C. The strength of the weld decreased sharply as the welding temperature was increased or decreased. Similar results were obtained by Barak et al. [18], who used the same system for welding of incisions in corneal tissues of rabbits.

In this work, we applied a similar technique for welding cuts in the urinary bladder. By using the system, it was observed that temperature control of 55 ± 5°C can be achieved (see Fig. 1). The temperature fluctuations in this case were much larger and they were probably related to movement of the physician's hand. Better temperature control near 55°C with stability of ± 2.5°C was achieved by Shenfeld et al. In that study, the fiber tips were held by a mechanical fixture at a small distance above the 18-gauge needle puncture wounds.

To study the long-term strength of welds, we generated wide openings (8–12 mm) in the urinary bladder of Sprague-Dawley rats and then sealed them with a CO_2 laser. In two rats, the bladder was opened to the abdominal cavity, to assess if such an opening in the bladder was fatal. Both rats died within 36 hours. To determine the best protocol for the healing in rats, five animals were operated on by using different combinations of stay-stitches, welds of the bladders, and decompressive intra-urethral catheters. These five rats are not included in our statistics (i.e., in Table 1).

Welding alone, excluding stay-stitches or catheter (but using temporary sutures), achieved an average survival rate of 74% in the 27 rats mentioned in Table 1.

CO_2 laser bladder welding seems to be effective in different animal models, when the surface temperature was kept at 55°C ± 5°C. In this study (and in the studies of other researchers), there had been no "controlled" method to experimentally determine the end-point for the welding procedure. The surgeon used the recommended surface temperature (55°C) and time (≈10 seconds) to obtain good welding. Yet, the histologic observation immediately after the welding procedure and 10 days after the procedure, clearly demonstrate the quality of the weld obtained.

Some researchers [1] have claimed that laser welding occurs at higher temperatures. The optimal temperature has not yet been defined. It would be advisable to have a well-defined calibration procedure to make sure that the reported temperature measurement represents the true surface temperature of the tissue. Parameters such as exposure duration, laser energy power, laser wavelength, and variation in tissue heating have to be optimally determined. This study supports the feasibility of CO_2 laser tissue welding in the urinary bladders of rats, rabbits, and cats. By measuring the temperature of the laser-heated tissue, reliable feedback control was obtained without vaporization or carbonization of the bladder wall.

Some researchers have reported the use of biological solders to enhance the bond strength [26–29]. In some of these works, the actual temperature of the biological glues may not have been accurately measured. Our system can be used for precise temperature control, even when using such biological solders.

The CO_2 wavelength is strongly absorbed by water. Because water is the major constituent of biological tissues, most of the CO_2 energy is absorbed in the topmost layer of the tissues. By increasing the duration of the exposure, while keeping the surface temperature of the tissue at 55°C ± 5°C, thermal buildup occurred and heat was transmitted to deep layers, enabling us to weld thick bladder tissues. In this case, the heat spread laterally, causing welding of a larger spot. We have successfully used other lasers (e.g., GaAs or Nd:YAG) for welding, and transmitted their energy through other delivery fibers (e.g., silica glass). In these cases, we were still able to use the radiometer with its "sensing" AgClBr fiber for monitoring and controlling the surface temperature during welding. Therefore, our system may be modified and used with lasers whose radiation penetrates deeper into tissues, and this could be more suitable for welding of thicker tissues. This modification will be tested in the future on thick bladders.

The improved calibration procedure that was introduced in this work takes into account a change of the tissue emissivity that may occur during the laser irradiation. There are other radiometric methods that address the same issue. An extremely useful solution for this problem is to use multispectral radiometry [30]. This is a much more complicated method, but it will be used in the future to assess the accuracy of the surface temperature measurement.

SUMMARY

We have developed a prototype of a fiberoptic laser welding system. The distal tips of two fibers were mounted on a hand-piece that made it easy for the physician to carry out the welding. With this system, we demonstrated the feasibility of CO_2 laser welding of urinary bladders in various animal models. We carried out early experiments on rats, whose urinary bladder is very thin. The large number of experiments made it possible to modify and improve the system. We then carried out successful experiments on cats whose bladders are much thicker and much more similar to human bladders.

Laser-tissue welding is an important application of tissue heating by laser irradiation. It remains an experimental surgical technique in urology, with the potential advantages of providing an immediate watertight closure, avoiding the introduction of foreign materials. The gold standard for bladder wall closure remains the running suture with an absorbable thread, which, at present, is less time consuming, less expensive, and safer. This study supports the feasibility of bladder wall welding. This is clearly demonstrated by a long-term follow-up evaluation of the morphology and efficacy of laser welding. In addition, the CO_2 laser used offers advantages of low cost, small size, and widespread use. It is likely that laser welding will be less dependent on the skill of the surgeon.

The fiberoptic system makes it possible to carry out laser welding in areas that cannot be treated with the nonfiberoptic systems mentioned above, such as the back of the bladder. Moreover,

the two optical fibers shown in Figure 1 could be easily inserted through the ancillary channel of an endoscope. This development opens the possibility of using the fiberoptic system for endoscopic laser welding of tissues.

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